13 NOV 1947

MR No. L5G06

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

July 1945 as
Memorandum Report L5G06

THE EFFECT OF SOME DESIGN PARAMETERS ON DITCHING CHARACTERISTICS

By John R. Dawson

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NACA

WASHINGTON

MR No. L5G06

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

and the

Air Technical Service Command, Army Air Forces

THE EFFECT OF SOME DESIGN PARAMETERS ON DITCHING CHARACTERISTICS

By John R. Dawson

SUMMARY

The purpose of this report is to provide designers of airplanes with information that will be helpful in obtaining good ditching characteristics in new designs. The results from a number of model tests and reports of actual ditchings are used as a basis from which to draw conclusions as to the effect on ditching performance of general arrangement, interior arrangement, fuselage shape, and other design parameters. The characteristics of several types of ditching aids that could be incorporated in a design are also discussed.

INTRODUCTION

The designer of an airplane has control over many factors that will affect the chances of survival of its occupants from a ditching. Since a considerable variation in ditching performance is found between designs that have similar performance in the air, it is evident that it is possible to choose values of design parameters that will give some measure of ditching safety without appreciable sacrifice in aerodynamic properties. A difficulty in achieving this end arises from the lack of knowledge of how the various design parameters affect ditching performance.

In the past few years a considerable number of ditching tests have been made with models by both the NACA and the British RAE. (The results of many of the NACA tests are unpublished.) These tests have been primarily concerned with finding how to get the best results out of existing airplanes, without making major changes in them. As a result there have been few systematic investigations of the type that would isolate the effects of specific variables. However, the tests have led to some conclusions that will be useful to the designer.

Model tests can give information on the motions of the airplane when ditching but data on the ability of personnel to withstand the motions and subsequently to escape from the sinking airplane must be obtained from other sources. Full-scale experiments must by their nature be relatively few but the available reports of actual ditchings have given information on these phases.

In the present paper the effects of a number of design parameters on ditching characteristics are given for the purpose of providing designers with information that will be helpful in obtaining good ditching characteristics. The conclusions on these effects have been obtained from a study of the results from both the NACA and British tests as well as reports of actual ditchings. With the existing state of knowledge regarding ditching many of the conclusions that have been drawn must be tentative and subject to confirmation from more systematic work than has yet been done.

The following ditching characteristics may be influenced by the designer of an airplane: (1) availability of good ditching stations, (2) hydrodynamic performance of the airplane, (3) means for rapid escape of crew, and (4) availability of equipment for survival at sea. It is desirable to obtain the optimum combination of all these characteristics. However, it is primarily the effects of design parameters on (1) and (2) that are considered in this paper.

Ditching characteristics may be affected indirectly by changes in parameters through their effects on other characteristics of the airplane. An outstanding example of this is the effect of landing characteristics (speed and controllability) on hydrodynamic performance. The necessity for precise control in a water landing, particularly if on a rough sea, is obvious. Increasing landing speed tends to cause more violent behavior and also to increase the damage to the airplane which may in turn cause a further deterioration in hydrodynamic performance. This cumulative effect makes it extremely difficult to obtain good hydrodynamic performance or good ditching stations if the landing speed is high. Consequently, all feasible measures for reducing the landing speed at the time of ditching should be considered.

GENERAL ARRANGEMENT

Location of Wing

Since a major portion of the buoyancy available for keeping the airplane afloat comes from the wing, it is desirable to have the wing placed low with respect to the fuselage so that the crew can keep above the water until they escape. Tests have shown, however, that under some circumstances a low wing may have an adverse effect on hydrodynamic performance.

If the flaps on a low wing are very strong, as they are in a dive bomber such as the SB2C-1, both NACA and British tests have shown that in their lowest operating positions they may cause the airplane to dive. The strength of flaps that can be used without causing dives probably depends on many factors but if the flaps can withstand a normal load greater than 300 pounds per square foot, the possibility that they may cause a low-wing airplane to dive should be considered.

A low wing on a multiengine airplane leads to a low position for the nacelles and this is usually disadvantageous for ditching. (See Engine Arrangement.)

Even where the configuration is such that diving does not occur, NACA tests with a model of the B-17 airplane (reference 1) have shown that a low wing may cause very high decelerations in landings made at a low attitude. While low-attitude landings are usually undesirable because of the higher landing speeds that they require, they may sometimes be unavoidable.

These considerations lead to the conclusion that the safest position of the wing is slightly above the bottom of the fuselage.

Engine Arrangement

Variation in the number of engines does not in itself have a consistent effect on ditching performance, but differences in ditching performance are obtained as a result of changes in engine arrangement because of the changes in nacelle and radiator locations that result. (See Radiators.) The usual type of engine nacelle when placed low tends to act as a "water brake" and increases decelerations. In an experiment with a model of the B-17 airplane it was found that when the wing incidence was decreased so that the nacelles projected below the fuselage they would cause the model to dive. It is generally better to place the nacelles well above the level of the bottom of the fuselage but if it were feasible to make nacelles with a type of bottom that turned up to form a scow-shaped bow, low nacelles would contribute to both longitudinal and lateral stability and longitudinal decelerations would be decreased.

Choice of engine arrangement sometimes affects the fuselage arrangement considerably and leads to unusual configurations such as that of the P-38 airplane where the tail surfaces are carried on extensions of the engine nacelles. There is not yet enough data to give general conclusions on the effects of such variations.

Location of Tail Surfaces

The location or type of tail surfaces appears to have little effect on ditching performance. However, the location of the tail surfaces affects the shape of the fuselage and this may in turn have large effects on hydrodynamic performance. (See Fuselage.)

Arrangement of Landing Gear

Tricycle-type landing gears require that a large hatch be provided for the nose wheel. Unless especial care is taken to make this hatch strong it will fail. In no case have the model tests shown that such a failure will cause diving but secondary failures that ensue as a result of the water pouring into this opening may be extensive enough to endanger nearby personnel. In general, the conventional landing gear having a tail wheel appears to give a better arrangement for ditching than the tricycle gear, provided that all wheels are retracted. If, however, consideration is given to the provision of any of the devices discussed under Ditching Aids, the tricycle landing gear provides structural members that are advantageously located to carry the concentrated load of the ditching aid. Methods of minimizing the hazards of a nose-wheel installation are suggested in reference 2.

NACA tests with models (reference 3) indicate that in ditchings made with wheels lowered, a dive may be expected. This confirms the results from British tests and from a considerable number of reports of actual ditchings, although there have been some ditchings with wheels down in which diving did not occur. The NACA tests indicate that any one wheel except the tail wheel may cause diving. In one case a nonretracting tail wheel was found to cause the model to skip and behave somewhat violently but no diving was caused by it.

FUSELAGE

Strength

If fuselages were of such strength that their bottoms would remain undamaged in a ditching, their shape would perhaps have only a secondary effect on ditching safety. Tests of many models including a wide range of fuselage shapes have shown that undamaged fuselages cause no worse motion than skipping or porpoising except when there are excrescences on their bottoms. If skipping and porpoising did not in turn tend to cause further damage they would not ordinarily be very dangerous to a well-braced crew.

Unfortunately ruptures of the bottom of the fuselage must be accepted as a normal condition in ditching. British model tests (reference 4) indicate that in smooth water the total load over a large area would be equivalent to a uniform load of the order of 10 pounds per square inch. However, the results given in reference 5 indicate that local pressures in a ditching may be many times this value and great damage was sustained by the reinforced airplane on which these pressures were measured. These results are not inconsistent with the pressures for seaplane bottoms that are generally of such shape that they would be subject to lesser pressures than fuselages. It cannot be said that such high local pressures will exist in all ditchings. If very high pressures do occur they may remain in one locality only for very short periods of time so damage will not necessarily be extensive in every ditching. Nevertheless the probability is large that these peak pressures will exist for a sufficient length of time to cause rupture of the bottom at almost any point not designed to take them. Once the bottom has been ruptured a large area may be torn away or crushed in.

The necessity for designing fuselage bottoms to withstand even greater pressures than encountered by flying boats would impose a severe weight penalty. Possible methods of reducing the damage sustained by fuselages of ordinary strength are suggested under "Ditching Aids." As an alternate to the use of such methods it is desirable to obtain designs that will cause a minimum of danger to personnel when the fuselage is broken open.

Critical Region

The middle third of the fuselage length appears to be the critical region in which failure of the bottom may cause diving. Openings of less than one-third the fuselage width even in this critical region have generally not caused dives in model tests.

Parts of bomb bays fall in this critical region. Since bomb doors are frequently less strong than the adjacent fuselage bottom, a considerable number of model tests have been made with bomb doors either removed or arranged to fold inward under pressure of a uniform load corresponding to their estimated strength. Failure of the bomb doors has caused models of some airplanes to dive but other models have made smooth runs when the bomb doors failed. These differences in performance appear to be due to many factors.

Shape

There is evidence that fuselage shape is one of the important factors that affects the ability of an airplane to withstand failure of the bomb doors without diving but a few attempts to eliminate diving or produce it by changes in the shape of the fuselage have been unsuccessful on models. There are not yet available enough data from which to obtain design rules that will insure shapes of fuselages that can withstand large failures without causing a dive and its resultant high decelerations. Nevertheless, such trends as have been deduced are given under the headings that follow. In general, only small differences in performance are indicated by the specific factors considered. The relatively large differences in performance that have been attributed to differences in fuselage shape appear to be due to an accumulation of minor effects.

Plan form.- Apparently changes in the length of the fuselage forward of the center of gravity (within the limits of current practice) affect hydrodynamic performance only slightly. The ratio of the length forward of the center of gravity to the total length of the fuselage averages approximately one-third for bombers and one-fourth for single-engine fighters. Differences in this ratio give no consistent differences in hydrodynamic performance for either class of airplanes, and the fact that fighters are generally reported to have poorer ditching characteristics than bombers is attributed to other differences.

Tests made by the NACA with a model of the B-24 airplane showed that increasing the length of the portion forward of the center of gravity by 11 percent caused no appreciable change in performance. Increasing this length by 28 percent (giving an approximation of the PB4Y-2 configuration) reduced the diving tendency but did not completely eliminate diving.

A large degree of plan-form curvature in combination with profile curvature may increase the effects of the latter (see below) but there have not yet been found any other effects thay may be charged to plan-form curvature.

Profile.- There is some evidence that a high degree of longitudinal curvature in the forward part of the fuselage contributes to diving tendencies. Efforts to verify this conclusion by direct experiment have so far been unsuccessful, however.

A high degree of longitudinal curvature in the after end of the fuselage causes the airplane to trim up soon after touching the water. (See references 6 and 7.) This tendency to trim up, of course, tends to keep the forward part of the airplane out of the water until the speed has decreased appreciably, and if no structural failure occurred it would perhaps be advantageous. However, failures of the bottom may be expected to occur in such a way that suction on the stern is released suddenly; pitching that follows causes the forebody to slap the water with extremely heavy impact and may end in a dive. A high degree of longitudinal curvature on the rear of the fuselage, therefore, tends to contribute to violent motion, extensive structural failure, and high decelerations.

Cross section.- Although a flat bottom is a very efficient planing surface, fuselages having circular or elliptical cross sections appear to be as stable dynamically (both in pitch and yaw) as those with nearly rectangular cross sections. Since flat bottoms are subject to much higher bottom pressures and are structurally less efficient for carrying bottom pressures, it is advantageous for ditching to use circular or elliptical cross sections.

Comparisons made on the basis of the seaplane load coefficient C_Δ indicate no consistent differences in performance due to variations in the width of fuselages. $\left(C_\Delta = \frac{\Delta}{wb^3},\right.$ where Δ is load on the water; w, the specific weight of water; and b, the beam.$\left.\right)$ In a representative group of airplanes C_Δ was found to vary from 1 to 5, and over most of this range there were examples of designs that would dive and also examples that would not.

Protuberances

Model tests have shown that protuberances on the bottom of the fuselage may cause diving even when the fuselage is not ruptured. A study of the available data indicates that protuberances located aft of the center of gravity are most liable to cause dives.

Radiators.- Radiators projecting below the fuselage aft of the center of gravity have caused dives but no such difficulty has been encountered with radiators placed under the nose.

Turrets.- Belly-gun turrets and radar housings placed forward of the center of gravity have, in general, caused no diving or other violent motions when tested on models. However, on the B-17 (reference 1) it was found that the belly turret installed aft of the wing caused diving of the model. Experiments indicated that even if it were possible to retract this turret halfway, it would cause the wing to submerge sufficiently to give high decelerations although diving would be stopped. British model tests showed that if the turret on the B-17 airplane breaks off quickly enough, smooth landing runs will follow. Model tests by both the RAE and the NACA showed that the hole that would be left by jettisoning the turret would have little effect on hydrodynamic performance although there exists the possibility that water entering such a hole might tear away a large enough portion of the bottom to cause dangerous effects.

Chin turrets have been found to cause little change in the hydrodynamic characteristics of models.

Gun housings.- Gun blisters such as those on the B-26 airplane (reference 7) and on one version of the A-20 airplane (reference 6) have had no appreciable effects on model performance. Similarly the 75 millimeter gun installation in the nose of the B-25 airplane (reference 8) had no effect on model performance.

Antennas.- Streamline antennas (having diameters less than 15 percent of the fuselage width) such as those beneath the B-26 and B-32 airplanes have caused no noticeable effect on the performance of models.

Interior Arrangement

Effects on hydrodynamic performance.- When a rupture occurs in the bottom of the fuselage, the motion of the airplane is influenced by the arrangement of bulkheads and other large surfaces that the water may strike. Model tests indicate that the bulkhead that is normally aft of bomb bays will increase the severity of dives even though a great part of it tears away when the water strikes it.

When water breaks in the bomb doors it strikes the wing spars of some airplanes such as the B-29. In the case of the B-29 model it was found that protrusions on the under surface of the spar or the insertion of a bulkhead above it tended to cause dives although results were inconsistent. The performance of the B-29 model, however, was particularly sensitive to small changes in it, and, in general, it appears that such differences in the interior arrangement of the bomb bays will not have so much effect.

The use of shallow bomb bays covered by a strong ceiling (as in British practice) helps to provide very good ditching positions for the crew. Reducing the depth of bomb bays, however, generally requires an increase in door area which in turn may increase the difficulties of obtaining strong doors. NACA model tests indicate that, if bomb doors break in, the depth of the bomb bay has little effect on the motion of the airplane unless there are protuberances that have a large transverse area below the ceiling of the bomb bay. In such a case, reducing the depth of the bomb bay may increase any diving tendency that exists.

There is at present no evidence from model tests that the arrangement of bulkheads and floors in the forward part of an airplane has any pronounced effect on its motion. However, no tests have been made to study this directly.

Effects on safe location of personnel.- The availability of good ditching stations for personnel will in some measure compensate for unavoidable deficiencies in hydrodynamic characteristics. Model tests show that decelerations in severe ditchings may exceed 10g but decelerations of this order can apparently be withstood by personnel if they can be braced against or strapped to a unit of the airplane that will not give way. Danger from parts of the airplane being broken off and thrown against occupants cannot be completely eliminated but the provision of adequate strength in some obvious hazards, such as overhead turrets, can be made.

Naturally the location of escape hatches in the upper part of the fuselage and close to ditching positions is imperative. The provision of at least one escape hatch for each three occupants is suggested as a design rule in reference 2. Crew members seated in cockpits are already partly out of the airplane and in a position to escape quickly provided that restraining harness can be released at once.

Fuselages sometimes break in two either just forward of or in the rear of the wing. Considering the protection that would be obtained from the wing and the desirability of being in the upper part of the airplane, the safest location for a ditching station appears to be above the rear part of the wing.

It would seem that pilots of fighter airplanes which have cockpits over the rear wing spar have an excellent chance to survive a ditching but available reports of ditchings do not generally bear this out. It must be concluded that this relatively good ditching location does not compensate for the poor hydrodynamic performance frequently found in this type of airplane. In the case of bombers or other large aircraft it is logical to arrange for ditching stations either above the wing or directly aft of the rear spar depending on the position of the wing. Personnel at ditching stations forward of the wing are subject to crushing from broken parts of the airplane pushed in by the water but in the upper part of the fuselage this danger can be minimized by a strong bulkhead and a strong floor. Pilot's compartments can thus be made reasonably safe.

There seems to be no question that the lower part of the nose of the airplane is the most hazardous location during a ditching. The nose may be generally expected to be crushed in some manner and it is imperative that crew members who are stationed in the nose shall be able to get out of it before a ditching is made.

Any ditching station directly on the bottom of the fuselage is dangerous because the plating of the fuselage may be ruptured by the water at any point and this may occur directly underneath or immediately in front of such a ditching station.

The extreme rear of the fuselage appears to be less dangerous than the nose but there is danger of this part breaking completely off from the rest of the airplane. This danger is increased by provision of turrets and other openings at the rear of the wing that tend to weaken the bending strength of the fuselage.

That portion of the fuselage between the tail surfaces and the bomb bays is hazardous in most bombers because (1) water is liable to pour aft from bomb bays, (2) turret openings increase the danger of the fuselage breaking aft of the wing, and (3) it is necessary for the crew to sit or lie on a light flooring strip only a few inches above the bottom plating. In airplanes where these objections can be overcome, fairly good ditching positions can probably be arranged in this part of the airplane.

DITCHING AIDS

In attempts to find means of improving the hydrodynamic performance of a few existing airplanes, experiments have been made with a number of schemes. Results from a few of the NACA tests on such schemes are given in references 3 and 9. If consideration can be given to some of these ditching aids during the design of an airplane, it should be possible to install them at much less cost in weight than would be necessary in applying them to a completed airplane. Where the operational requirements of an airplane demand a high degree of ditching safety some sort of ditching aid may be found to be the most efficient way of insuring such safety.

Hydroflaps

One method of preventing diving or "nosing in" during the high-speed part of a ditching run is to provide a device near the nose that will have sufficient hydrodynamic lift to furnish the requisite positive pitching moment. Experiments have been made by the NACA with flat planing surfaces, called hydroflaps, installed on models for this purpose.

Of a variety of hydroflaps that were tested, a narrow planing surface, having a trapezoidal plan form, and set at an incidence of 30° to the fuselage was the most effective on the B-24 model (fig. 1). The area of this hydroflap (6.25 square feet full scale) was only slightly more than one-half the area of the two leaves of the nose-wheel door.

The trapezoidal plan form gave smoother runs than were obtained from hydroflaps with rectangular plan forms. Flaps of less area or of higher aspect ratios also prevented dives, but the low aspect ratio hydroflap extending well below the bottom of the fuselage offers an opportunity of concentrating on a small strong area the high water pressures, obtaining at landing speeds. It is theoretically possible to set a hydroflap so that landings can be made on it alone, with the rest of the fuselage held clear of the water until a fairly slow speed has been reached; models have been made to do this. The possibilities of consistently obtaining such a landing with actual airplanes are unexplored but, with a hydroflap installation of this type only the rear of the fuselage could touch the water at high speeds and severe damage would be confined to that area.

If a hydroflap is of such dimensions that the fuselage near it can enter the water at high speeds, there is danger that failure of the fuselage may cause the hydroflap to be carried away.

A hydroflap could be made so that it is kept flush with the bottom of the fuselage until needed. Extending the trailing edge of the hydroflap to its operating position would be a part of ditching procedure. Tests made with a model of the TBU-1 airplane indicate that hydroflaps that have a curved cross section suitable to fit flush with circular or elliptical fuselages can be made effective hydrodynamically.

Hydrofoils

Two general methods of using hydrofoils to improve hydrodynamic ditching characteristics have been tried on models. In one method (see references 4 and 9) the hydrofoil is placed below the nose of the model with a positive incidence and in the other it is placed somewhere aft of the center of gravity with a negative incidence so that it will tend to hold the tail down. (See reference 3.) Both schemes have been effective in improving the performance of models but in the NACA tests it was found more difficult to obtain an effective installation in the rear than in the front.

In the case of the B-24 model the rear installation that was effective in stopping diving required a hydrofoil of very large area and it had to be located several feet below the bottom. Arresting gear hooks are located at a point suitable for installing a hydrofoil that would pull down. In model tests of the SB2C-1 airplane the standard arresting gear hook caused decelerations to be increased under some conditions. When this hook was replaced by the largest hydrofoil that could be retracted into the hook well, the tendency to dive was reduced under some landing conditions but it was not effective in stopping all dives.

A hydrofoil placed beneath the nose offers the possibility of reducing fuselage damage by keeping the fuselage clear of the water at high speeds in a manner similar to that of the hydroflap. Under proper conditions smoother runs have been obtained with a nose hydrofoil than with a hydroflap. However, the landing attitude has a more critical effect on the performance of hydrofoils than on that of hydroflaps. Furthermore at full-size landing speeds hydrofoils are subject to cavitation effects not obtained at the landing speeds of models. Until more data on these effects are obtained the forces on hydrofoils running at high speeds can be determined with less accuracy than those on planing surfaces, and full-size applications of hydrofoils are subject to correspondingly greater uncertainties in performance.

Hydrospoilers

A spoiler placed on the bottom of the forebody eliminated diving of the B-24 model (reference 3). Tests made with several spoilers indicated that to be effective such a spoiler would have to project a minimum of 3 inches (full size) below the fuselage and be extended up the sides slightly. The first spoilers tried were rectangular in cross section but the triangular spoiler shown in figure 2 gave satisfactory results. A triangular spoiler might be installed so that it could be opened out in the same manner as cowl flaps. In order to be effective on an airplane, however, the bottom of the fuselage forward of such a spoiler would need to be strong enough so that it would not fail and permit the spoiler to be carried away by the water. This requirement is difficult to meet and puts the spoiler at a disadvantage when compared with a long hydroflap.

The manner in which the spoiler prevents diving has not been investigated but at present it appears that the spoiler eliminates some negative pressures just aft of the nose. The triangular spoiler, of course, acts also as a hydroflap of very large aspect ratio.

Flotation Gear

Flotation gears consisting of some type of inflatable bags designed to increase the time a landplane will float have been used to some extent with naval aircraft for many years. (See reference 10.) The bags may be either ejected from the airplane or inflated within it. Bags placed inside the airplane appear to have three advantages: (1) they can be inflated by manual control before ditching, (2) when inflated they may furnish some support against bottom pressures on the fuselage, and (3) in rough water they will be subject to less chafing than external bags.

It is, however, difficult to find space in the fuselage that will not be so far aft of the center of gravity that the added flotation will be ineffective. The British have provided flotation gear in the bomb bays of the Wellington and other bombers. Data from actual ditchings indicate that the average flotation time for the Wellington airplane was increased from $2\frac{1}{2}$ to 8 minutes by the flotation gear.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCES

1. Tarshis, Robert P., and Stewart, Thelma: Ditching Tests with 1/16-Size Models of the Army B-17 Airplane in Langley Tank No. 2 and on an Outdoor Catapult. NACA MR No. L5C24, Army Air Forces, 1945.

2. Anon.: Landplane Ditching.
   Manual Prepared. Air Sea Rescue Bull. No. 4, Air Sea Rescue Agency (Washington), Oct. 1944, pp. 4-8.
   Part II - Factors Which Determine Ditching Characteristics. Air Sea Rescue Bull. No. 5, Air Sea Rescue Agency (Washington), Nov. 1944, pp. 4-9, 12.
   Part III - Ditching Safety in Transport Landplanes. Air Sea Rescue Bull. No. 6, Dec. 1944, pp. 5-8.

3. Fisher, Lloyd J., and Steiner, Margaret F.: Ditching Tests with a 1/16-Size Dynamic Model of the Army B-24 Airplane in Langley Tank No. 2 and on an Outdoor Catapult. NACA MR No. L5D07, 1945.

4. MacPhail, D. C., and Ross, J. G.: Model Tests of the Alighting of Landplanes on the Sea. Part 3. Liberator. Rep. No. Aero 1770, British R.A.E., Aug. 1942.

5. Steiner, Margaret F.: Accelerations and Bottom Pressures Measured on a B-24D Airplane in a Ditching Test. NACA MR No. L4K14, 1944.

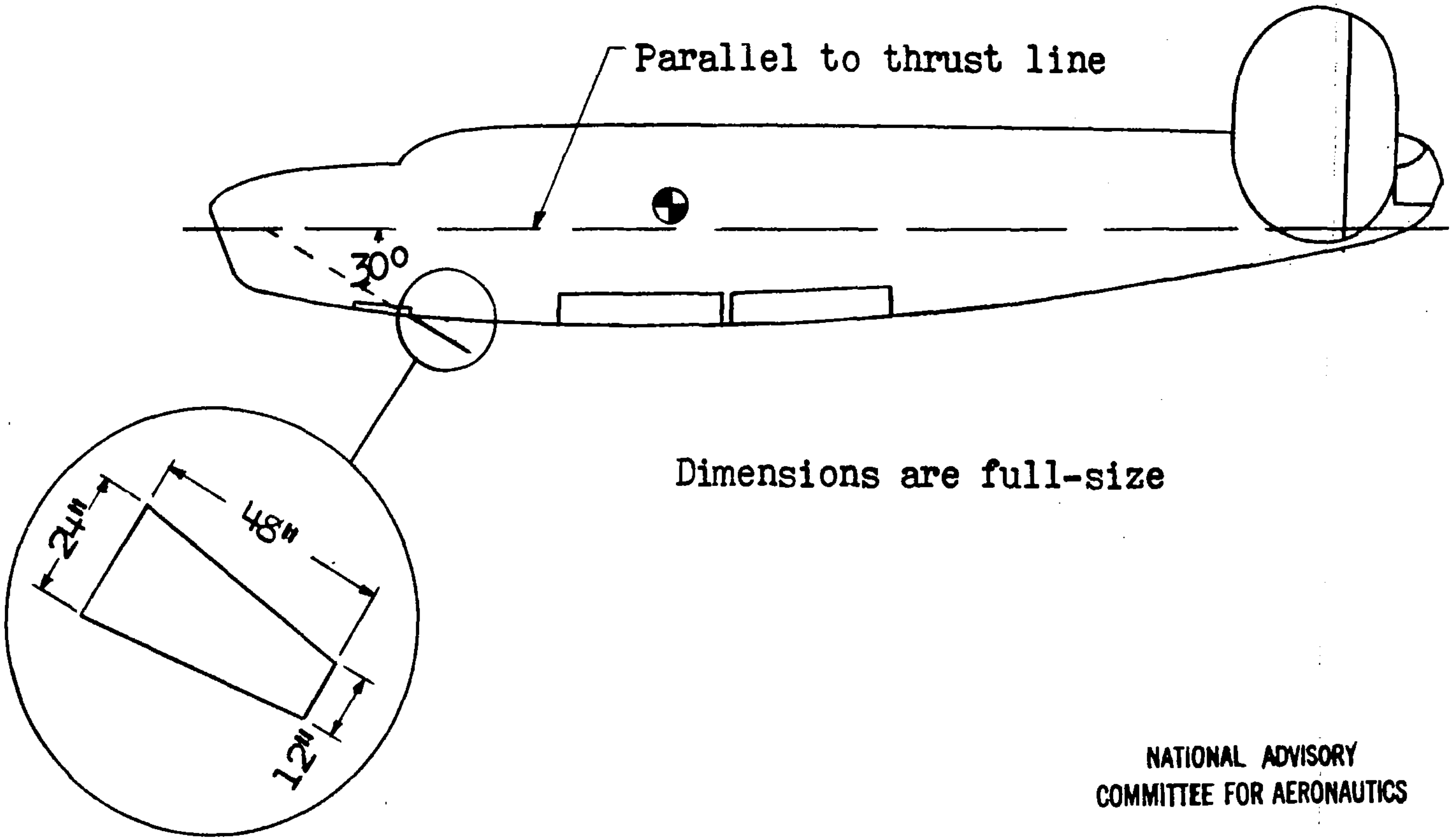
6. Dawson, John R., and Jarvis, George A.: Ditching Tests with a 1/10-Size Model of the Army A-20A Airplane. I - Calm-Water Tests in NACA Tank No. 2. NACA MR, Nov. 18, 1943.

7. Fisher, Lloyd J., and Steiner, Margaret F.: Ditching Tests with a 1/12-Size Model of the Army B-26 Airplane in NACA Tank No. 2 and on an Outdoor Catapult. NACA MR, Aug. 15, 1944.

8. Jarvis, George., and Steiner, Margaret F.: Ditching Tests with a 1/11-Size Model of the Army B-25 Airplane in NACA Tank No. 2 and on an Outdoor Catapult. NACA MR No. L4J11, 1944.

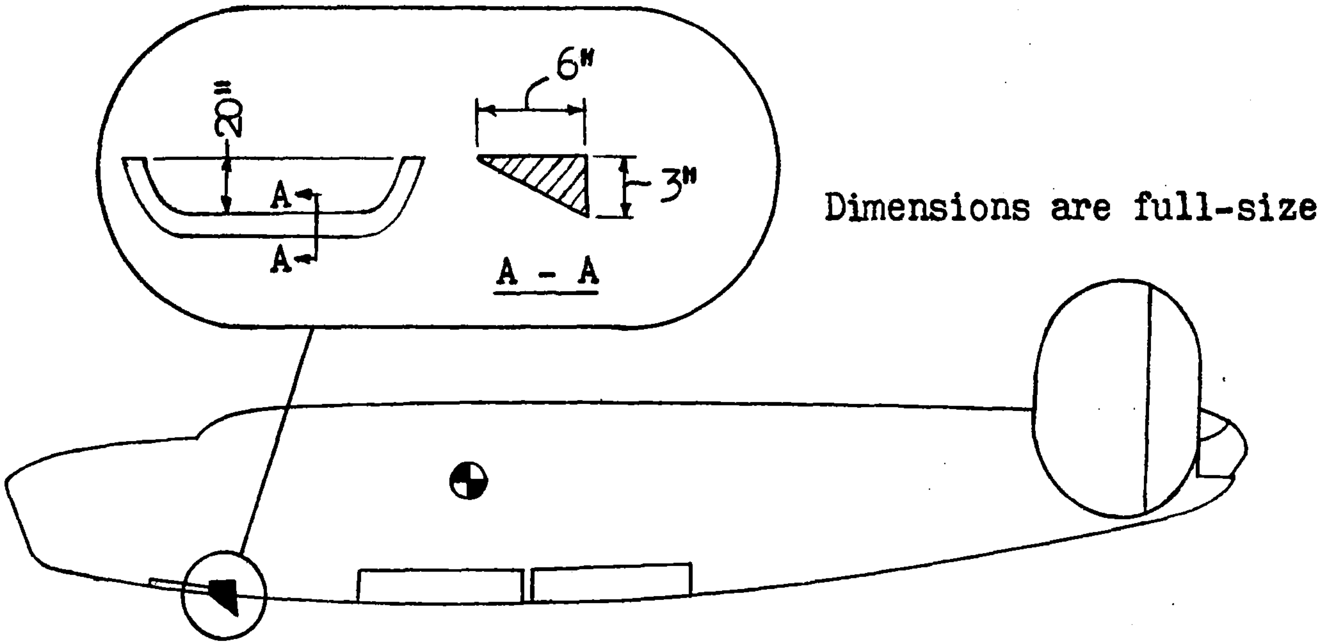
9. Steiner, Margaret F.: Ditching Behavior of Military Airplanes as Affected by Ditching Aids. NACA MR No. L5A16, 1945.

10. King, H. F.: Wheels over Water. Flight, vol. XXVIII, no. 1406, Dec. 5, 1935, pp. 598-600, and no. 1407, Dec. 12, 1935, pp. 618-621.



NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

Figure 1.- Trapezoidal hydroflap as tested on a model of the Army B-24 airplane.



NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

Figure 2.- Triangular hydrospoiler as tested on a model of the Army B-24 airplane.